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# ANALYSIS OF WEAR AND SEM CHARACTERISTICS ON FERROUS COMPOSITES THROUGH POWDER METALLURGY METHOD

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***ABSTRACT***

***Iron is the most commercially used metal in various fields from the ancient period. Nowadays its application in the marine and aerospace fields gets reduced gradually due to the density and ease of corrodibility nature. In this study the iron properties are optimized without compromising its hardness and strength. The metal matrix is formed in iron by adding alumina and bagasse fly ash as an alloying element. This study is done by powder metallurgical route. Also, experimental analysis is done on composite material after the sintering process at austenitization temperature. The wear test are taken for composite to check mechanical properties and the Scanning Electron Microscope (SEM) is used to understand the fine dispersion of alloying element in the composite. Finally, the samples are benchmarked with each other to identify that it is valuable one.***

***KEYWORDS: Iron, Density, Metal Matrix, Alumina, Bagasse Fly Ash, Powder Metallurgy, Austenitization, Mechanical Properties & SEM***

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**Original Article**

## 1. INTRODUCTION

Powder metallurgy technique is the unconventional and economical way of producing ferrous matrix composite. But, with the stir casting technique it is difficult to produce a particulate reinforced composite. In this present method suitable modifications were carried out on powder metallurgy method to take care in production of composite and segregation of reinforcing particle. But when compared to the present method, particle infiltration is relatively a difficult process. The requirement of composite material has gained popularity in these days due to their various properties like low density, good wear resistance, good tensile strength and good surface finish. Among various particulates used, fly ash is one of the least expensive and low density reinforcement available in huge quantities as solid waste by product in thermal power plants. Materials with good strength to weight ratio are becoming very essential in modern engineering designs especially for automotive and aerospace applications whereimproved machine efficiency and reduced fuel consumption are critical requirements to be satisfied. Also, modern infrastructures, equipment and machineries that are currently developed require materials that have a good combination of properties to match servicedemands [1]. Titanium alloys are used in aerospace and automotive applications because of its high specific strength, stiffness and good machinability but its wear resistance is inadequate. To eliminate this property lag Boron Carbide (B4C) ceramic particles are reinforced with Ti-6Al-4V (titanium aluminum composite material) through powder metallurgy (PM) route [2]. Reinforcement particles are

mixed with base alloy for the weight percentage of 0, 5 and 10 so as to analyze the effect of reinforcements on mechanical, corrosion and wear properties. The powder metallurgy helical gear has been applied on power take off and the finite element method is used on analysis of the characteristic of the transmission gear. The transmission efficien cy experiment has been done to prove that Powder metallurgy gear transmission has high efficiency, long service life, low manufacturing cost and enhance the power transmission capability [3]. Magnesium (Mg) and Magnesium alloys have attracted immense attention as a biomedical implant material due to favourable mechanical properties and biocompatibility. Biodegradable nature of Magnesium dismisses the need of revision surgery for removal of implant. Porous Mg- foams are advantageous as presence of pores 5 allows the higher degree of Osseo integration [4]. The mechanical properties of the porous foam material is a function of its density, thus a Finite Element Method (FEM) approach is required to predict the behavior of Magnesium foam under various stresses for real-time application. The author has attempted to quantitatively assess the mechanical properties of Mg foam with 40-45% porosity with 100- 300μm pore size. Concrete is the single most widely used construction material in the world today. It is used in buildings, bridges, sidewalks, highway pavements, house construction, dams, and many other applications [5]. The key to a strong and durable concrete are the mix proportions between the various components. Less cement paste can lead to more voids, thus less strength and durability while more cement paste can lead to more shrinkage and less durability. The gradation and the ratio of fine aggregates to coarse aggregates can affect strength and porosity. The mix design should also achieve the desired workability of concrete so as to prevent segregation and allow for ease of placement. Crushing plant is one of important processing units in mining industry. Process sequences in mineral mine processing are started with crushing plant unit, to reduce bigger mineral size into desired size to use in the next processing. In the iron ore mining industry, fine iron ore waste is produced within 30% of total feeds in crushing plant unit [6]. The reinforcement material used in this study is iron mill scale particles, while the hybrid matrices 6 are silica sand, magnesia, and betoniesclay [7]. Iron mill scale particles were sourced from Universal Steel Nigeria Limited located in Ogba, Lagos. Silica sand was obtained from the beach of the Lagos Atlantic Ocean (bar beach). Aluminum matrix composites (AMCs) are the competent material in the industrial world. Due to its excellent mechanical properties, AMCs is widely used in aerospace, automobiles, marine etc [8]. Especially in the defence application, are continuously striving hard to find the materials that suit their specific requirements. The improvement in production methods and finding the alternate materials are a few options to meet the above requirement. The process of drilling is commonly used in modern manufacturing, as most of the produced parts contain bore holes or threads [9]. When drilling conventional steel materials, a number of recommendations [8, 9, 10] can be found regarding tool geometry and cutting parameters, both of which play an important role in improving this process. Nevertheless, in the case of difficult-to machine materials, such as sintered iron based powder metallurgy steels, the drilling process is still part of a less researched area of manufacturing science. It is all despite the fact that these materials are becoming increasingly common due to their favorable properties. In the present research of a systematic study onFe-$Al_2O_3$ (Ferrous alumina composite)Metal Matrix composites (MMCs) prepared by Powder Metallurgy have been reported [10]. It is expected that the outcome of the experimental studies will be helpfulin designing and developing Metal Matrix composites for critical industrial applications.

## 2. METHODOLOGY

### Preparation of Test Specimens

Iron metal powder having 92.5% purity and particle size in the range of 250-300 mesh, active aluminum oxide having particles size in the range of 250mesh and bagasse fly ash of 250 mesh are used as starting materials. The

composite selected for present investigation contains aluminum oxide ($Al_2O_3$) and fly ash in 3, 6 and 9% by weight. Mixed powders were ball milled dry with the powder to ball ratio of 1: 2 using ceramic balls as the grinding and mixing media. Mixed powders were compacted using a hydraulic press under a constant load of 100 bar. Green compacts were sintered in the temperature $1150^0$C for 3 hours at a heat rate of 0.5 deg/min. After sintering, the compacts were machined on bench grinder. To grind a sintered sponge metal from reduction, jaw and hammer crushers are used above all. Grinding in a jaw crusher is performed between a fixed jaw and a moving one and represents the first stage of disintegration, where a coarse powder is obtained. This is subsequently milled to a final product in some type of a mill. In a hammer grinder the material is crushed using an impact of hammers attached on a rotor.

## 3. RESULTS AND DISCUSSIONS

### 3. 1 SEM Analysis

The samples of MMCs for metallographic examination were prepared by grinding through bench grinder and different size of grit papers. The microstructure observed by using scanning electron microscope (SEM-PMU, Thanjavur) and its specifications are given in Table 1.

**Table 1: Specifications of SEM**

| | |
|---|---|
| **Magnification** | Secondary electron image:10 to 60,000x<br>Backscattered electron image:10 to 30,000x |
| **Observation Modes** | High vacuum and low vacuum modes |
| **Electron Gun** | Small grid gun integrating filament and wehnelt |
| **Accelerating Voltages** | Secondary electron image: 3 stages 15 kV/10 kV/5 kV<br>Backscattered electron image: 2 stages 15 kV/10 kV |
| **Specimen Stage** | Manual control for X and Y<br>X: 35mm, Y: 35mm |
| **Maximum Specimen Size** | Diameter 70 mm, height 50 mm |
| **Signal Detection** | High vacuum (secondary electron image, backscattered electron image)<br>Low vacuum (backscattered electron image) |
| **File Format** | BMP, TIFF, JPEG |
| **Operating System** | Windows 7 |
| **Automatic Functions** | Auto focus, auto stigmator<br>Auto contrast/brightness control<br>Auto gun alignment |
| **Composition** | Base unit, power supply box, PC, LCD, rotary pump |
| **Dimensions (WxDxH; Main Unit)** | 330 (W) x 490 (D) x 430 (H) mm |
| **Power** | Single phase AC240 V (960 VA)<br>Fluctuation ±10%, grounded |
| **Room Temperature** | 15°C to 30°C |
| **Humidity** | 60% or less |

The sample1 is having 6% of alloying element (3% of $Al_2O_3$ + 3% of fly ash) and its SEM image is shown in Figure 1. The powder alumina got mixed with iron metal powder during mixing. Even though the size of fly ash is 250 micron, it will segregate in some place. But due to segregation it exhibit poor wear resistance properties

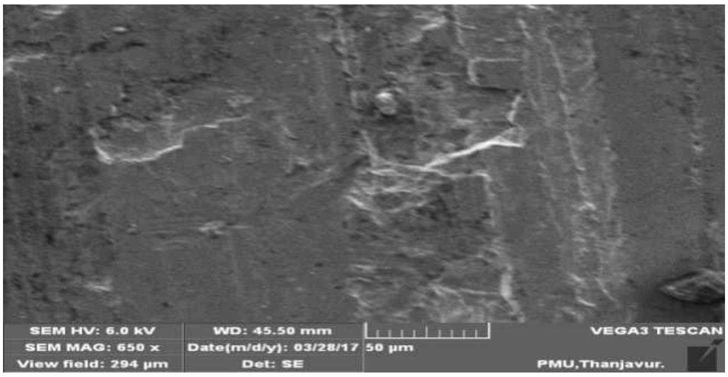


**Figure 1: SEM Image for 6% Alloying Element**

In sample 2 the alloying element is 12% (6% Al2O3 + 6% of fly ash). There is a fine dispersion of material as shown in Figure 2. The materials are segregate in one corner but the properties are quit be improved for this sample. Even, the wear resistance is also more compared to other samples.

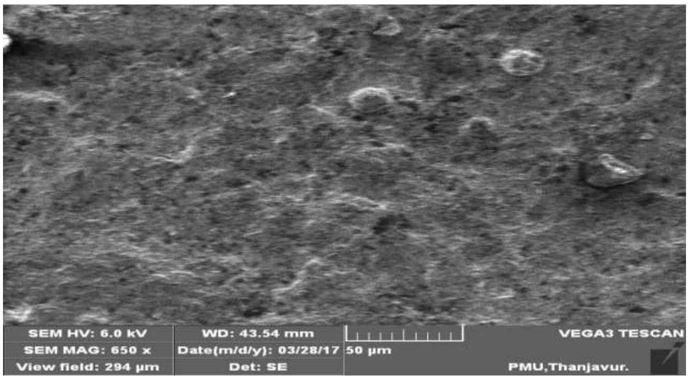


**Figure 2: SEM Image for 12% of Alloying Element**

When analyzing the sample 3 the presence of 18% of alloying element is not finely dispersed as shown in Figure 3. But, when comparing with sample 2 the wear properties are reduced and it is more than sample 1. The porous hole was reduced gradually in all samples. This is due to increase in fly ash content.

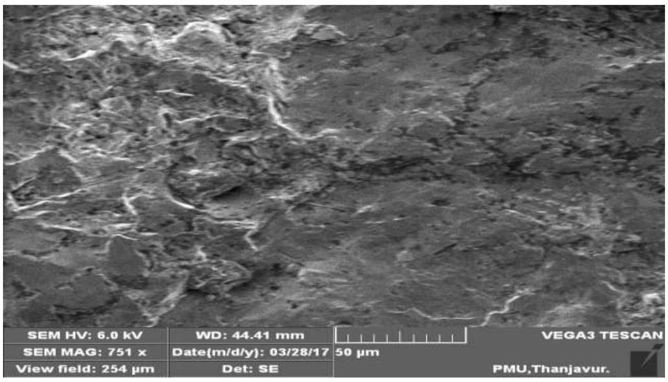


**Figure 3: SEM Image for 18% of Alloying Element**

## 3. 2 Wear Analysis

The Cylinder size of the wear analysis equipment is 150 mm diameter & 500mmlength. The material of coarse abrasivesheet having 60grade. Equivalent revolution of the disc plate is 84times. Rotational frequency of the equipment is 40 +/- 1rpm. Load applied for our research is 1kg. Table 2 shows the properties of all samples.

**Table 2: Wear Properties of Samples**

| s.no | Sample ID | Initial weight (g) | Final weight (g) | Abrasion loss (g) | % | RANK |
|---|---|---|---|---|---|---|
| 1 | Fe 94% + Al2O3 3 % +FLY ASH 3% | 13.5341 | 13.0448 | 0.4893 | 3.61 | 3 |
| 2 | Fe 88% + Al2O3 6 % +FLY ASH 6% | 14.1526 | 13.6968 | 0.4558 | 3.22 | 1 |
| 3 | Fe 82% + Al2O3 9 % +FLY ASH 9% | 13.7822 | 13.3316 | 0.4506 | 3.27 | 2 |

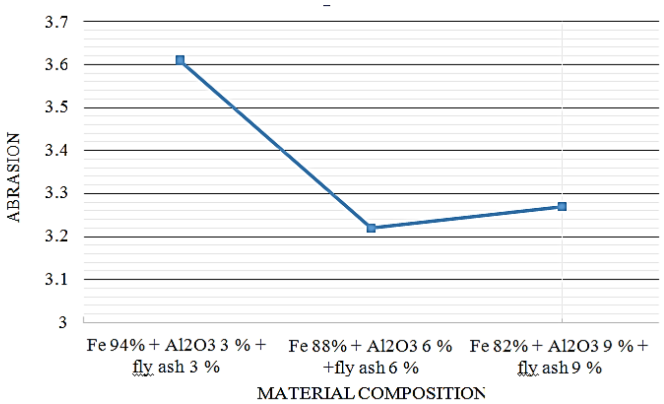


**Figure 4: Wear Resistance of Samples**

The addition of alloying element shows a satisfactory effect in improving the wear resistance. This is to be expected because both alumina and fly ash have excellent tribological properties. The aluminium oxide is hard abrasive material and fly ash is excellent filler material. While comparing the three samples with each other the sample 2 (Fe 88% + $Al_2$ $O_3$ 6% + fly ash 6%) exhibit good resistance against wear. But, sample 3 wear resistance value was reduced as shown in Figure 4 and Figure 5. Various other parameters also affect the resistance. As from the literature survey increases in percentage of alloying element properties will reduce properties of thecomposite.

**Figure 5: Wear Tested Samples**

## 4. CONCLUSIONS

For dispersion of alloying metal into the matrix and powder is to be mixed in a ball mill and mixing time is a major parameter in alloying. The powder that used for the composite should have greater in grain size above 100 microns then only the metal can form during compaction. Else, the binder should be added without affecting properties of the composite metal. The porosity could be avoided by sintering process at suitable temperature and the mechanical properties could be improved the sintering of iron composite. The coating is made on the material by aluminium paint to avoid oxide formation on surface. Even the wear for sample 2 is ultimate than other, it had the abrasion of 3.22% due to presence of fly ash. So, it is suitable for bearing applications. The sample 3 got the average mechanical properties with excellent surface finish. So, it suitable for making furniture's and window frames. Sample 2 will have superior mechanical properties. So, it could be a suitable replacement for cast iron with reduced porosity. It would be economically suitable for applications. The sample 3 had good surfacefinish.

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